Duration of Soil Water Content between Field Capacity and Wilting Point and Its Effect on Growth of Some Aerobic Rice Cultivars (*Oryza sativa* L.)

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Abstract: Soil water content management is important cultural practices to improve growth and yield of crops. This report was conducted to investigate the duration of soil water content between field capacity (FC) and wilting point (WP) and its effects on growth of aerobic rice cultivars. Experiment was carried out using factorial design *i.e.* Varieties (*Inpago 8* (V1), *IR64* (V2) and *Situbagendit* (V3), combined with 3 soil types based on locations taken *i.e.*: *Maros* (M), *Gowa* (G) and *Jeneponto* (J) for evapotranspiration and together with control (unplanted) for evaporation measurements. Watering requirement was calculated based on data from *soil tester device*. Results indicated that varietal difference was not significantly different in all soil source type. Longest soil water contents duration between FC and WP (18 days) recorded by *Maros* soil under evaporation and 14 days under evapotranspiration. However, plant performance was low compared to other soil source perhaps due to soil structure. The highest number of leaves per plant was shown by GV2 and JV2 (19.4 leaves), plant height by GV1 (30.21 cm), plant fresh weight in GV3 (28.47 g), plant dry weight by GV3 (8.1 g), number of tillers/plant was obtained by the treatments combination GV1 and GV2 (6 tillers) and shoot/root ratio by JV2 (4.9). Understanding the duration of soil water content between FC and WP for each soil types is very important to saving water and our results showed that it could be implemented for a better rice production in aerobic rice in the very near future

Keywords: *Soil water content; field capacity; wilting point; aerobic rice*

1. Introduction

Soils are composed of organic matter (stuff that used to be alive, like plants and animals) and small inorganic matter. There are three basic soil types: sand, silt, and clay. Sand is comprised of tiny rock fragments and is the roughest in texture. Clay becomes sticky or greasy when wet, and very hard when dry. Silt is between sand and clay in texture. Soil physical, chemical and biological properties, affect many processes in the soil that make it suitable for agricultural practices and other purposes (Nichols *et al*., 2004). Texture, structure, and porousity influence the movement and retention of water, air and solutes in the soil, which subsequently affect plant growth and organism activity (Gaidner and Miller, 2004).

The proportion of pores filled with air or water varies, and changes as the soil wets and dries. When all pores are filled with water, the soil is 'saturated' and water within macro pores will drain freely from the soil via gravity. 'Field capacity' (FC) is the amount of water remaining in the soil after all gravitational water has drained. Remaining water is held in micro pores via attractive 'capillary' forces or surface tension between water and solids. Unlike gravitational water, capillary water is retained in the soil and can only be removed by plant uptake or evaporation. The amount of capillary water that is available to plants is the soil's 'water holding capacity' (WHC) or 'plant available water' (PAW). This water is available for plant uptake until the 'permanent wilting point' (PWP) is reached, a point at which water is held too tightly by the soil for plants to extract it (Carter, 2002).

Many researchers confirmed that differences in growth and yield especially in rice depend upon soil water contents. Results showed that dry-matter production, number of tillers was significantly varying between FC and PWP. Furthermore, shoot nutrients concentration significantly decreased with decreasing soil water content, while soil redox potential increased. Shoot–dry matter production and tiller number when saturated were significantly higher than in other treatments and Significant correlations were observed between the shoot nutrients concentration and tiller number at maximum tillering stage in the field and pot experiment, respectively (Hongbin *et al*., 2007). Otherwise, the reasons of significant and insignificant effect may be due to many factors such as organic matter percentage in soil, reduction of water uptake by root system of plant, fluctuation in photosynthesis rate which there is a great relation between soil types, water content and photosynthesis, genetic constitutions and soil composition such as air, mineral and water which reflect to plant performance (Mohd *et al*., 2015; Louis *et al*., 2013; Juliana *et al*., 2016)

Knowledge of the soil water content at field capacity and wilting point is also very important for assessing plant water requirements, irrigation scheduling, and predicting crop responses to irrigation, modeling solute transport, and assessing soil suitability for different land uses (Salter, 1967). The goal of the research was to investigate the duration of soil water content between field capacity (FC) and wilting point (WP) and its effect on growth of some aerobic rice varieties.

2. Materials and Method

2.1. Location and Description of Experimental Layout

Experiments were conducted in greenhouse of the Hasanuddin University (UNHAS) Faculty of Agriculture, Department of Agronomy, Makassar, Indonesia, during 2015-2016. Materials used in this study were seed of three varieties which were *Inpago 8* (new potential variety, V1), *IR64* (Susceptible cultivars, V2) and *Situbagendi* (local aerobic rice cultivars, V3).

Seeds were obtained from Indonesian Center for Rice Research (ICRR) in Sukamandi, West Java. Three different soil types from rice cultivated area (*Maros, Jeneponto and Gowa)* was analyzed for some chemical and physical properties in the Laboratory of Soil Science, Soil Science Department, Faculty of Agriculture, Hasanuddin University, Makassar Indonesia (Table 1). Thermometer, drinking water, pots, digital balance, digital cameras, sprayer, measuring tape and writing tools were used later during the experimental protocols.

Experiment was carried out using two-factor factorial design *i.e.:* variety and paddy filed soil source. Three pots with each different soil types were planted with each of the three rice varieties. The number of experimental units were 36 units with controls made with pots without plant (to calculated water loss through transpiration) to determine the duration of water between (FC) and (WP) of some aerobic rice varieties under different soil types which affected by evapotranspiration. The minimum, maximum temperature and relative humidity during the period of study was measured daily (Table 2).

2. 2. Observed Parameters

2.2.1 Number of days from field capacity to wilting point

Soil water content was calculated by gravimeter (g water / g soil) (ISO 11465 1993) confirmed by used of *soil tester device* every three days after irrigation and the number of days from field capacity and wilting point were calculated.

2.2.2 Number of leaves per plant

Number of leaves per plant were recorded after 15, 30, 45, 60, 75, 90, 105 and 120 days respectively after sowing date and the means was calculated.

2.2.3 Plant height (cm) per plant

Plant height measured after 15, 30, 45, 60, 75, 90, 105 and 120 days, respectively after sowing date and the means was calculated.

Table 1. Soil sample analysis during the experiment

Source of	Sand	Silt	Clay	Texture (USDA)	pH	Organic Matter			CEC	AEC
	……%……					C%	N%	C/N	(cmol(+) kg^{-1})	
Maros	45	26	29	Clay Loam	6.6	2.24	0.13	19	21.25	12.24
Gowa	47	25	28	Sand Clay Loam	5.7	1.45	0.14	10	19.25	14.66
Jeneponto	43	38	19	Loam	7.4	3.17	0.17	19	22.32	9.09

Table 2. Mean of temperature and relative humidity during experiment

Parameter measured		Mid June 2015	July	August	September	Mid October 2015
Temperature	Max	30.35	32.03	31.89	32.45	34.27
	Min	23.46	22.90	24.13	22.37	23.37
Relative	Max	70.17	59.42	58.73	52.83	43.31
Humidity	Min	58.33	48.97	46.97	43.43	34.13

2.2.4 Total Number of tillers/hill

Total number of tillers/hill recorded weekly until final numbers during harvest were registered and the means was calculated.

2.2.5 Plant fresh and dry weight (g)

Fresh and dry weight (g) of plant were recorded after 15, 30, 45, 60, 75, 90, 105 and 120 days respectively after sowing date and the means was calculated.

2.2.6 Shoot/Root Ratio

Was measured following the formula from Wood and Roper (2000). *Shoot/Root Ratio* = Dry Weight for top of plant /Dry Weight for roots

2.3 Data Analysis

Data was analized by standard analysis of variance techniques (Gomez and Gomez, 1984) using Statistical Package System software (SPSS) version 2.1 and means of significant difference were separated using Duncan's multiple range test (Duncan's test).

3. Results and Discussion

3.1 Duration of Soil Water Content between Field Capacity and Wilting Point

Data collected during 120 days from sowing to harvest showed that the Duration of Soil Water Content between Field Capacity and Wilting point on *Maros* soil (MV0) was found to be every 18 days, *Gowa* soil (GV0) every 10 day and *Jeneponto* soil (JV0) every 11 days under evaporation period, but under evapotranspiration the duration was every 14 days which was achieved by MV1, MV2 and MV3 treatments, between 9-10 days and between 10-13 days on (G) and (J) respectively (Fig. 1). Water loses faster under evapotranspiration affected by 8-9 days compared with transpiration. Thus, Gowa soil (GV0) recorded the shortest period of duration between (FC) and (WP) considering types of soil texture which is sandy clay loam soil. Sand content (47%) and silt content (25%) were analyzed to be the highest and lowest, respectively, compared with other soil sources. To prolong the duration, organic matter addition is needed which is located between soil pores to improved soil physical

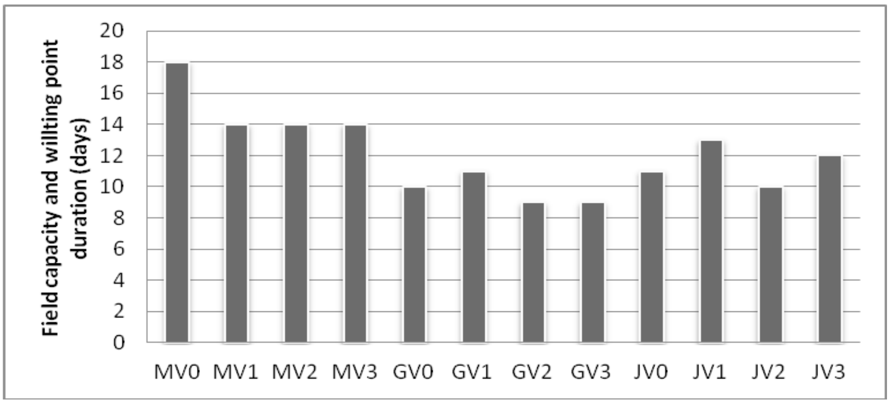

Figure 1. Duration of Soil Water Content between Field Capacity and Wilting Point affected by evaporation and evapotranspiration of some aerobic rice cultivars under three types of soil condition. Soil source type: *Maros* soil (M) *Gowa* soil (G) and *Jeneponto* soil (J); Rice variety: *Inpago 8* (V1), *IR64* (V2) and *Situbagendit* (V3).

properties. Thus, in general, clay soils or those with higher content of organic matter (upper 5% organic matter) present a higher soil water holding capacity (average field capacity ranging from 35 to 40% volume). In contrast, a sandy soil has a lower water holding capacity and field capacity typically ranges from 10- 15% volume.

3.2 Number of Leaves/Plant

Analysis of variance indicated that there was no significant difference between varieties (V) and interaction within (varieties (V) × soil types (S) but there was a very high significant difference between soil types (S). The maximum and minimum number of leaves/plant was recorded in the treatments GV2 and JV2 which were 19.4 and 7.8 leaves, respectively (Table 3). Highest differentiation effect on leaves number/plant was significant between soil types especially in Gowa soil, whereas *Jeneponto* has the lowest, because of reduction of water uptake in spite of water was available, controlled by root traits such as root dry weight and root length. The answer of this case regarding to increase root trait is required with increase soil root distribution and penetration.

3.3 Plant Fresh and Dry Weight (g)

The effect of different soil water content duration between field capacity and wilting point management on plant fresh weight (g) of aerobic rice cultivars corroborate that there was a very high significant effect between soil types (S), but unfortunately there was no significance between varieties (V) and their interaction (S × V). Plant fresh weight (g) was substantially highest for treatments GV3 (28.47 g) compared with lowest one shown by the treatment MV1 (6.76 g), (Table 3).

Among plant dry weight (g) statistical analysis had significant between soil types (S) but there been no significant difference between varieties (V) and interactions (soil types (S) × varieties (V). Plant dry weight (g) was highest in the treatment GV3 (8.1g)

Table 3. effect of duration of soil water contents between Field Capacity and Wilting Point on some vegetative parameters of some aerobic rice cultivars (Inpago 8 (V1), IR64 (V2) and Situbagendit (V3)) for three soil types (A) *Maros* soil (B) *Gowa* soil and (C) *Jeneponto* soil

Treatments	Number of leaves/ plant	Plant height (cm)	Plant fresh weight (mg)	Plant dry weight (mg)	Number of tillers/ plant
MV1	8.4^{bcd}	22.53	6.76^{bcdefg}	2.05^{bc}	3^{bc}
MV2	14.1^{abc}	25.83	10.51^{bcdef}	6.5^{ab}	4^{ab}
MV3	10.9^{bc}	24.33	11.34^{bcdef}	3.26^{b}	3^{bc}
GV1	16.9^{abc}	30.21	24.23^{ab}	9.34^{a}	6^{a}
GV2	19.4^{a}	21	14.11^{bcde}	4.84^{ab}	6^{a}
GV3	18.2^{ab}	29.33	28.47^{a}	8.13^{ab}	5^{ab}
JV1	12.7^{abc}	29.67	15.67^{bc}	5.03^{ab}	4^{ab}
JV2	7.8^{bcd}	27.83	15.08^{bcd}	4.88^{ab}	4^{ab}
JV3	14.4^{abc}	26.33	12.94^{bcde}	4.11^{ab}	4^{ab}
SE□	2.23	3.07	3.83	1.67^{ab}	0.74
CV%	28.37	20.20	42.91	53.98	29.65

Figures not sharing the same letters differ significantly at p< 0.05 and lowest value obtained at treatment MV1 (2.05 g).

Gowa soil also registered highest record data about plant fresh and dry weight (g) resulted from high photosynthesis rate when the duration between field capacity and wilting point is low, thus high amount of water reached to the soil during vegetative and reproductive growth period of rice furthermore. There is a great relations between soil types, water content and photosynthesis rate otherwise, low water input affect chlorophyll related parameters. To look after the problem of low plant fresh and dry weight (g) revealed by Maros and, *Jeneponto* soil we recommend increased fertilization dose to be best practices.

3.4 Plant Height (cm)

Effect of soil water content duration between field capacity and wilting point on Plant height (cm) of the aerobic rice cultivars showed that there was no significant differences between soil types (S), varieties (V) and their interaction. Among treatments, the treatment GV1 reported the highest plant height (30.21 cm) and GV2 treatment was the shortest one which was 21 cm (Table 3).

The differentiation between plant heights maybe due to genetic constitutions between aerobic rice cultivars rather than soil water contents at the first stage of plant growth, but soil water contents possible to significantly reduced plant height at late stages. Therefore, it is indicated that soil water content can reduced the plant height and this reduction is enhanced by irrigation regime of higher interval which reflected to lower tillers and panicle and decreased yield. Select adoptable varieties to cultivate under irrigation system are best idea for helping water management.

3.5 Number of Tillers/Plant

The effect of soil water content duration between field capacity and wilting point on number of tillers/plant of some aerobic rice cultivars is presented in Table 3. Very high significance between soil types (S) was shown here, but there was no significant between varieties (V) and their interaction. The highest number of tillers/plant was obtained by the treatments GV1 and GV2 which was 6 tillers and the lowest was by the treatment MV1 (3 tillers).

The highest number of tillers which was recorded by Gowa soil interacted with V1 and V2 which was corelated to water and minerals uptake as a result of high value of root system density and soil types which correlated with bulk density (expresses the ratio of the mass weight dry weight to the total volume: the total volume includes both the solids and the pore space). Soil bulk density is important because it is an indicator of the soil's porosity, the porosity of soil is defined as the volume of pores in the soil, otherwise Gowa soil has highest value of soil density because for its high percentage of sand compared with Maros and *Jeneponto* soil.

The percentage between soil composition such as air, mineral and water was best in Gowa soil which reflected to an improved physiological root system process under irrigated area. To improve the characteristics of Maros and *Jeneponto* soil increasing bulk density is needed by increasing sand and organic matter percentage and pore, while decreasing the silt, clay and loamy percentage.

3.6 Shoot Dry Weigh (g), Root Dry Weight (g) and Shoot/ Root Ratio

Data analysis highlighted no significant difference between parameters which had mention above in the form of soil types (S), varieties (V) and interactions. Among Shoot Dry Weigh (g) highest value was registered by the treatment GV3 (5.42g) and lowest value obtained at treatment MV1 (1.6 g) (Table 4). Through Root Dry Weight (g) biggest amount was recorded by the treatment GV1 (3.1 g) and smallest one at treatment MV1 about 0.5 g (Table 4).

Shoot/ Root Ratio recorded the oldest number by JV2 treatment that about 4.9 and the youngest one was 2.2 in GV3 (Table 4). To explain the relation between shoot dry weights, root dry weight and Shoot/ Root Ratio also Gowa soil showed the highest root dry weight, Shoot Dry Weigh (g), and lowest Shoot/Root Ratio compared with others, the effective factors may be root system distribution in the form of root formation, and elongation of adventitious root. Root angle available assimilate and it's partitioning between shoot and roots and within the root system, and formation of lateral roots. To solve the problems of root distribution in Maros and *Jeneponto* soil cultural practices especially soil preparations through plowing, harrowing and sandy soil addition for improving soil texture and structure.

Our results indicated that the duration of soil water content between field capacity and wilting point under evaporation reported different period (days) between soil types, such as Maros soil every 18 days, Gowa soil every 10 day and Jeneponto soil every 11 days. However, the period decreased under evapotranspiration duration (every 14, 9-10 and 10-13 days on Maros, Gowa and Jeneponto, respectively). This may be due to different soil texture which corroborate Francis and Richard (2003) reports. Fine textured soils have an abundance of small pores and thus more capillary movement of water to the surface will generally occur in

Table 4. Effect of duration of soil water contents between Field Capacity and Wilting Point on shoot dry weigh (g), root dry weight (g) and Soot/ root ratio of some aerobic rice cultivars (Inpago 8 (V1), IR64 (V2) and Situbagendit (V3)) for three soil types (A) Maros soil (B) Gowa soil and (C) *Jeneponto* soil.

Treatments	Shoot dry weight(g)	Root dry weight(g)	Shoot/root ratio
MV1	1.6	0.5	3.2
MV2	4.3	2.2	3.6
MV3	2.6	0.7	4.3
GV1	6.2	3.1	2.8
GV2	3.2	1.7	2.4
GV3	5.42	2.7	2.2
JV1	3.7	1.3	3.01
JV2	4.0	0.9	4.9
JV3	2.8	1.3	2.6
SE±	1.05	0.82	0.88
CV%	48.65	94.75	47.08

Figures not sharing the same letters differ significantly at $p < 0.05$

fine textured than in coarse textured soils. Otherwise, different soil types in the form of the soil textures (sand and loamy sand) were found that its ability to water holding capacity ranged from 5 to 25% (Adamu and Aliyu, 2012).

Furthermore, soil scientist have recorded many factors directly or indirectly influenced soil physical, chemical and biological properties which in turn will affect many processes in the soil especially, transpiration, evaporation and evapotranspiration that make it suitable for agricultural practices and other purposes for example texture, structure, and porosity influence the movement and retention of water, air and solutes in the soil (Carter, 2002; Balba, 1995; Gaidner and Miller, 2004)

The significant effect among growth attributes may be true according to the importance of water in plant physiological activities, especially ones which depend upon cell activities. Many researchers agreed differences significantly vary between FC and PWP in growth and yield, especially in rice, depend upon soil water contents because water play famous role in cell division and metabolic activities. Their results showed that dry-matter production, number of tillers was significantly varying between FC and PWP or wet and dry (Hongbin *et al*., 2007; Belder *et al*., 2004; Bouman *et al.,* 2005). Beside that, high differentiation on leaves number/plant as significant effected between soil types, may be as a reduction of water movement between soil and root system thus, in spite of water available which controlled by root trails such as root dry weight and root length. (Nghia *et al*., 2015). Variation on plant fresh and dry weight (g) resulted from high photosynthesis rate when the time between field capacity and wilting point is short with enough amount of water added to the soil during plant growth period of rice. There is a great relations between soil types, water content and physiological aspects affected amount of water such as photosynthesis rate. Otherwise, low water input affect chlorophyll related parameters (Mohd *et al*., 2015).

Many researchers concluded that plant heights affected by soil water content during plant life cycle maybe due to interaction between genetic constitutions and environmental conditions rather than soil water contents alone at the first stage of plant growth. However, some times soil water contents were possibly significantly reduced plant height at late stages. Therefore, it is indicated that soil water content can reduced the plant height and this reduction is enhanced by irrigation regime of higher interval which reflected to lower tillers (Louis *et al*., 2013) and panicle and decreased yield and increased unfilled grain (Yoichiro *et al*., 2006; Chen *et al*., 2008; Juliana *et al*., 2016; Abbasi and Sepaskhah, 2011). In shoot/root ratio, a scientific report have written that the main and effective factors have its own influence: root system distribution in the form of root formation, and elongation of adventitious root. Root angle available assimilate and it's partitioning between shoot and roots and within the root system, and formation of lateral roots (Yoichiro-Kato *et al.*, 2007; Yoichiro *et al*., 2006).

However, insignificants difference may be as aresult of other factor such as decreased nutrients uptake by plant from the soil. This concept was proposed by Hongbin *et al.,* (2007) and Cabangon *et al*., (2004) stated that nutrients concentration significantly decreased with decreasing soil water content.

4. Conclusion

Water loses faster under evapotranspiration affected by 8-9 days compared with evaporation. Three soil types which were *Maros, Gowa* and *Jeneponto* calculated different number of days on water content from (FC) and (WP) that reflect its own specific effect on some growth attributes of rice cultivars such as, number of leaves/plant, plant height (cm), plant fresh and dry weight (g), number of tillers plant and shoot/root ratio.

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